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BIANNUAL STATUS REPORT NUMBER 5 FOR CONTRACT NOBSR-93175, 1 JAN--ETC(U)
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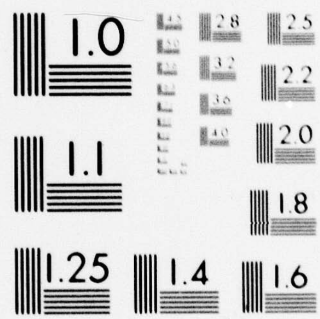

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

DEFENSE RESEARCH LABORATORY

THE UNIVERSITY OF TEXAS

AUSTIN, TEXAS 78712

Number

(6)

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1 January through 30 June 1967.

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Task 8515, Project Serial Number SF0010316

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DEFENSE RESEARCH LABORATORY
THE UNIVERSITY OF TEXAS AT AUSTIN
AUSTIN, TEXAS 78712

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Biannual Status Report No. 5 for Contract NObsr-93175
for period 1 January through 30 June 1967

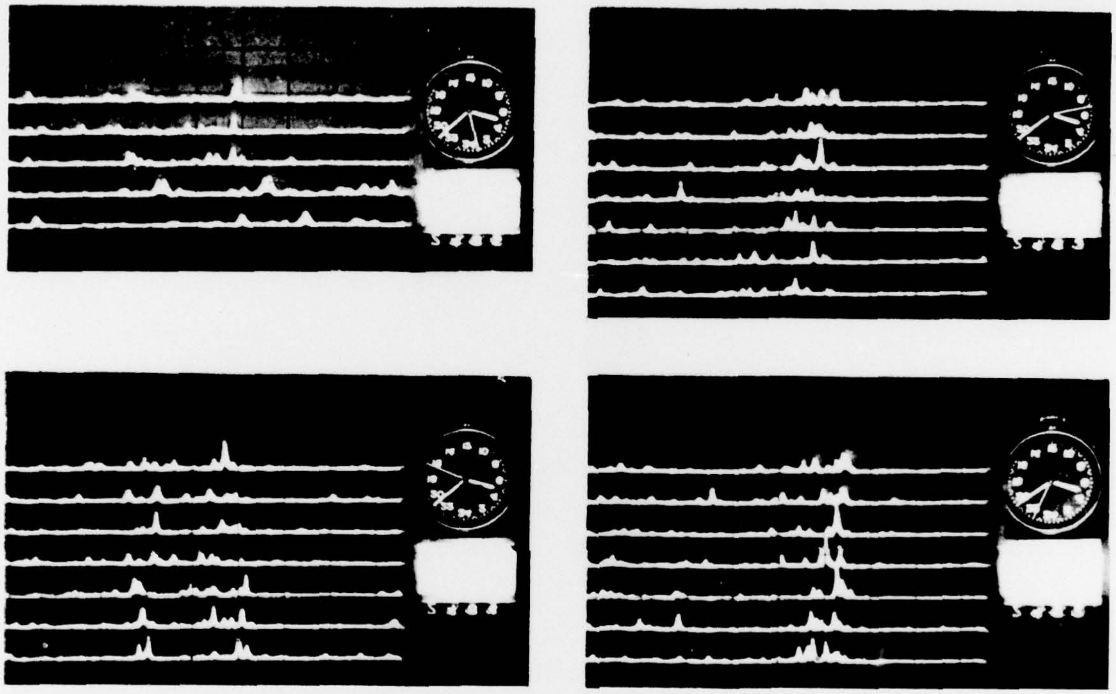
I. Task 8515, Project Serial Number SF0010316

Report on the

A. AN/SQS-23 Digital FM Classifier.
(K. W. Harvel, A. O. Herbst, and W. D. Howard)

(U) The correlator section of the FM classifier was considered fully operational on 13 January 1967. The sonar timing and control functions had been designed and built during previous reporting periods, but it was required that the classifier be used to process tapes recorded during the 1965 sea trip aboard USS SARSFIELD (DD-837). This necessitated certain temporary modifications in the classifier. In order to limit the effects of wow and flutter in the record and playback system, the correlator clock was disabled, and a new clock signal derived from the 40 kHz reference signal recorded on tape aboard the SARSFIELD was used instead. The transmit-receive interlock signal and the sonar dwell signal had to be derived from the 5 kHz transmit signal. Zero time and target gate pulses were obtained directly off of the tape.

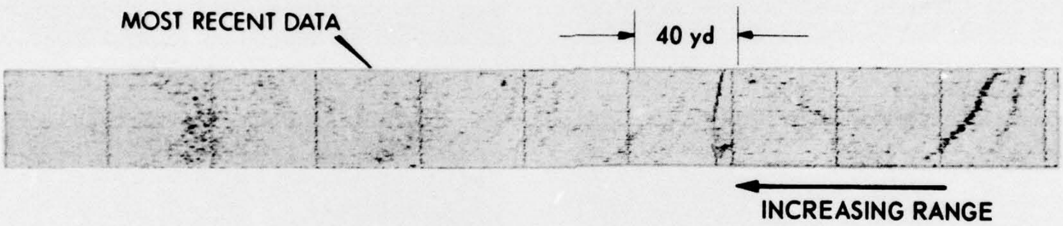
(C) During the third week of January the classifier was used to process selected SARSFIELD tapes. Photographs were made of the oscilloscope display on a ping-to-ping basis, with a total of seven reels of submarine data and one reel of nonsubmarine data being processed by the correlator. Late in the report period, some of these same tapes were played back again, but this time the correlator output was recorded on the Raytheon PER-196 paper recorder. Figure 1 shows photographs of the oscilloscope display of a nonsubmarine target. Figure 2 is a portion of the paper recorder display showing the same general target shown in Fig. 1. Figure 3 shows photographs of a submarine echo with a 195 deg aspect angle. Figures 4 and 5 illustrate submarine targets with 90 deg aspect angles.



TARGET RANGE: 750 yd
CLASSIFIER BANDWIDTH: 625 Hz
CLASSIFIER TIME-BANDWIDTH PRODUCT: 128
WINDOW: 400 yd

FIGURE 1
TYPICAL NONSUBMARINE TARGET
PHOTOGRAPHED FROM OSCILLOSCOPE DISPLAY
AN/SQS-23 DIGITAL FM CLASSIFIER (U)

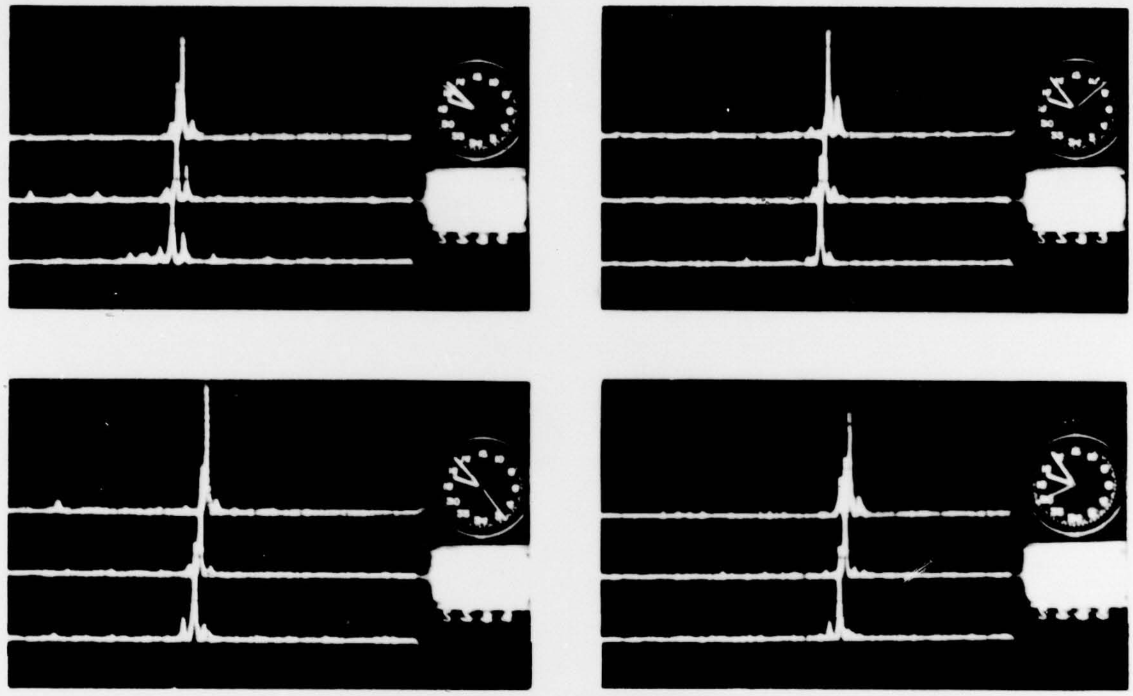
DRL - UT
AS-67-1348
AOH - RFO
9 - 20 - 67



TARGET RANGE: $\simeq$ 8000 yd
CLASSIFIER BANDWIDTH: 625 Hz
CLASSIFIER TIME-BANDWIDTH PRODUCT: 128
WINDOW: 600 yd (400 yd SHOWN)

FIGURE 2
TYPICAL NONSUBMARINE TARGET
RECORDED ON RAYTHEON MODEL PER-196 RECORDER
AN/SQS-23 DIGITAL FM CLASSIFIER (U)

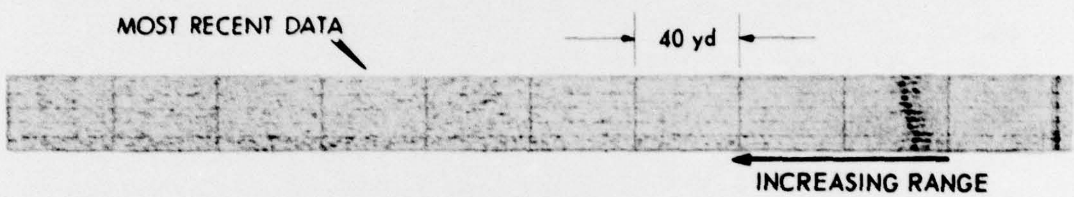
DRL - UT
AS-67-1349
AOH - RFO
9-20-67



TARGET RANGE: 3850 yd
CLASSIFIER BANDWIDTH: 625 Hz
CLASSIFIER TIME-BANDWIDTH PRODUCT: 256
WINDOW: 160 yd
TARGET ASPECT: 195 deg

FIGURE 3
TYPICAL SUBMARINE TARGET
PHOTOGRAPHED FROM OSCILLOSCOPE DISPLAY
AN/SQS-23 DIGITAL FM CLASSIFIER (U)

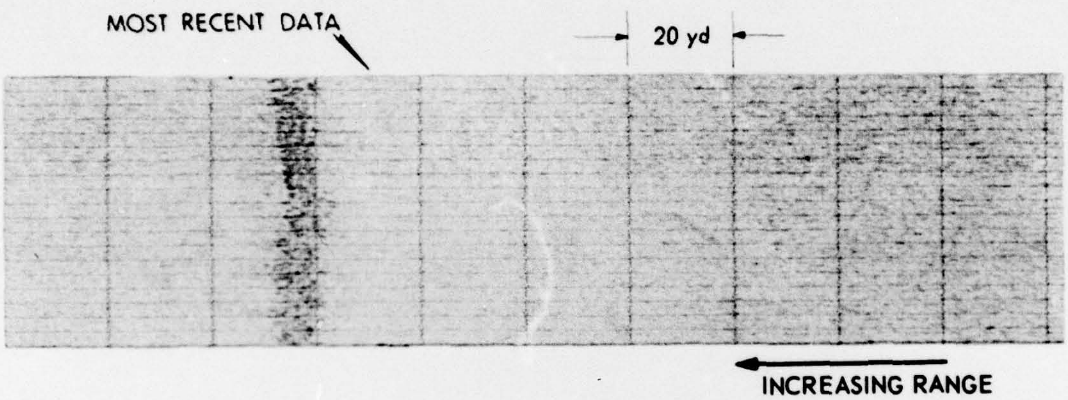
DRL - UT
AS-67-1350
AOH - RFO
9 - 20 - 67



TARGET RANGE: 4150 yd
CLASSIFIER BANDWIDTH: 625 Hz
CLASSIFIER TIME-BANDWIDTH PRODUCT: 128
WINDOW: 600 yd (400 yd SHOWN)
TARGET ASPECT: 090 deg

FIGURE 4
TYPICAL SUBMARINE TARGET
RECORDED ON RAYTHEON MODEL PER-196 RECORDER
AN/SQS-23 DIGITAL FM CLASSIFIER (U)

DRL - UT
AS-67-1351
AOH - RFO
9 - 19 - 67



TARGET RANGE: 4150 yd
CLASSIFIER BANDWIDTH: 1250 Hz
CLASSIFIER TIME-BANDWIDTH PRODUCT: 256
WINDOW: 300 yd (200 yd SHOWN)
TARGET ASPECT: 090 deg

FIGURE 5
TYPICAL SUBMARINE TARGET
RECORDED ON RAYTHEON MODEL PER-196 RECORDER
AN/SQS-23 DIGITAL FM CLASSIFIER (U)

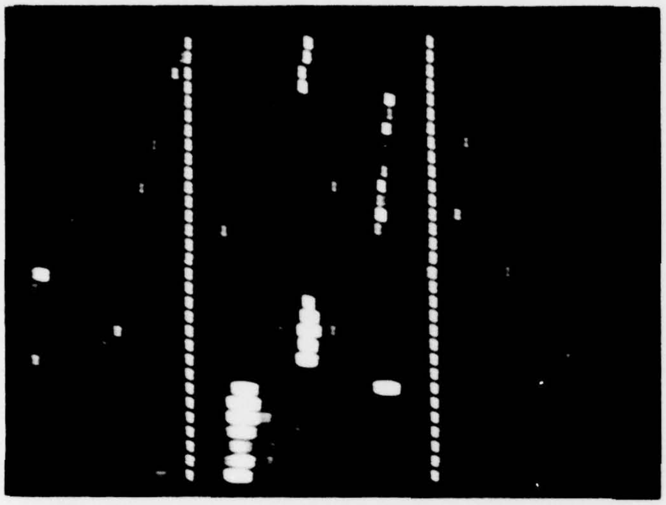
DRL - UT
AS-67-1352
AOH - RFO
9 - 19 - 67

(C) In addition, during the same period, Defense Research Laboratory (DRL) transcribed the output data of the correlator on 1/4 in. magnetic tape to be used with the IBM display on which tests were performed in the sonar van facility. Recorded on the 1/4 in. tape were the raw sonar signals from the original data, the output of the correlator, and the zero time pulse. For these IBM tests, DRL processed and re-recorded, within the correlator time-bandwidth capability, nine reels of nonsubmarine data and fifteen reels of submarine data. Figure 6 shows some typical IBM displays using Z axis modulation.

(U) The tape playback operations were concluded on 26 January 1967, and work was begun to ready the classifier for the April sea test. The two major problems remaining at this time were the completion of the design of the receiver AGC circuit and the assembly and test of the ODN servo circuits. The servo components and the AGC components were working on the bench by the middle of February, and both units were submitted to the shops for final assembly. Concurrent with these activities, the entire system was being connected in its final form.

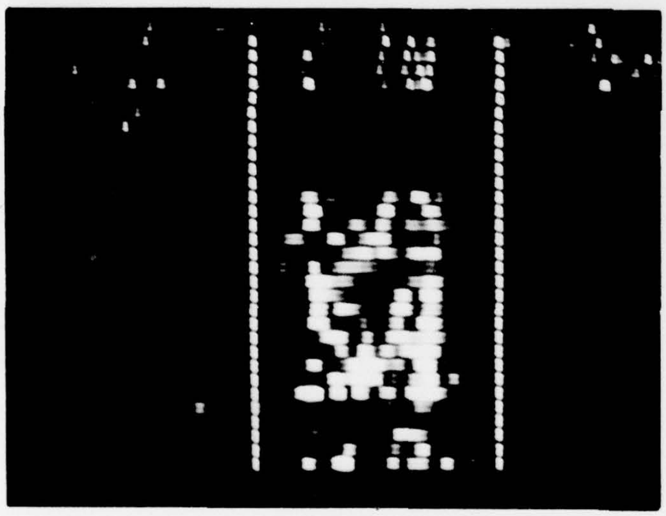
(U) In February the April sea trip was cancelled. DRL took the opportunity afforded by the cancellation to make improvements in the receiver, to improve the digital control and display circuits, to bring the system drawings up-to-date, and to take a close look at the PER-196 paper recorder.

(U) The paper recorder had received only limited use since it arrived at DRL, and no one had any experience in operating and maintaining the unit. A unified schematic of the signal electronics was prepared. Test points were added to the output stages to monitor calibrations, and calibration potentiometers were added to permit mode-to-mode calibrations. Calibration charts and procedures were prepared and added to the handbook. The start-stop circuitry was modified to



NONSUBMARINE TARGET

TARGET RANGE: 750 yd
CLASSIFIER BANDWIDTH: 625 Hz
CLASSIFIER TIME-BANDWIDTH
PRODUCT: 128
WINDOW: 250 yd



SUBMARINE TARGET

TARGET RANGE: 3270 yd
CLASSIFIER BANDWIDTH: 156 Hz
CLASSIFIER TIME-BANDWIDTH
PRODUCT: 256
WINDOW: 250 yd
TARGET ASPECT: BOW

FIGURE 6
TYPICAL NONSUBMARINE AND SUBMARINE TARGETS
PHOTOGRAPHED FROM IBM DISPLAY (U)

DRL - UT
AS-67-1353
AOH - RFO
9 - 19 - 67

permit operation from DEC logic. The FM classifier was again set up to analyze SARSFIELD tapes, and a limited number of tapes were processed to demonstrate the paper recorder display. Examples are shown in Figs. 2, 4, and 5. The paper recorder functions as well as can be expected considering the mechanical problems involved. One of the most severe problems remaining involves maintaining reliable electrical contact between the trolley bar and the stylus brushes. This as yet unsolved problem causes the edges of the display to be ragged, effectively narrowing the window as much as 20 yd. This raggedness is noticeable to some extent in Figs. 4 and 5. After the stylus brush is fully engaged in the trolley bar, the contact is reliable.

(U) The ODN system was completed during this report period. This system is composed of the remote Z_o servo unit and the pit-log servo repeater. The Z_o unit is mounted adjacent to the sonar transducer, and is designed to keep the sensing accelerometer level. The output of the accelerometer is amplified and integrated to give the classifier velocity information indicating lateral motion of the sonar transducer. To aid in calibrating this system, a special pendulum was constructed and used to approximate ship's roll. Alternating current (ac) signals generated by swinging this pendulum (or by the ship's roll) are integrated in the FM classifier for frequencies down to 0.1 Hz with an accuracy of ±2 percent.

(C) Near the end of this report period DRL was informed that there was a possibility of utilizing the FM classifier again aboard the USS SARSFIELD (DD-837) on extended HUK operations beginning about the middle of August. Based on this possible utilization of the equipment, efforts were again directed toward making the equipment ready for extended operation at sea.

B. Systems Analysis

(U) During the first half of CY 1967 more computer programs were written to increase signal processing and data handling capability, and updating and streamlining of old programs mentioned in Biannual Status Report No. 4 were continued. A brief description of these new programs and modified programs follow:

TESTLITE

(U) The operation of the A/D-D/A interface is tested with program TESTLITE. Included in the tests are the A/D and the D/A process, status bits, digital inputs, digital outputs, and the interrupt lines.

GENDATA4

(U) An analytical up-sweep linear FM transmit signal array A(t) and an echo array B(t) is generated by GENDATA4. The transmit array is given by:

$$A(t) = \sin\left[2\pi(f_o - \frac{W}{2T} t)\, t\right] \quad ,$$

where

f_o = center frequency
W = bandwidth
T = transmit pulse length

The echo array for a given $\dot{r}$ (range-rate) is computed from:

$$B(t) = \sin\left\{2\pi\left[\left(\frac{1 - \dot{r}/c}{1 + \dot{r}/c}\right)f_o - \frac{Wt}{2T} \cdot \left(\frac{1 - \dot{r}/c}{1 + \dot{r}/c}\right)^2\right]t\right\} \quad ,$$

over the interval

$$-\frac{1 + \dot{r}/c}{1 - \dot{r}/c}\ \frac{T}{2} \leqq t \leqq \frac{1 + \dot{r}/c}{1 - \dot{r}/c}\ \frac{T}{2} \quad ,$$

where

c = velocity of sound.

A cross-correlation function is computed over a window centered on a predicted time of maximum correlation, t max. Graphs are generated for either (1) correlation function vs lag for a given Doppler, or (2) the maximum correlation values vs Doppler for a specified Doppler range. The same operations can be performed for the analytical expression for a down-sweep linear FM signal.

CROSCORG

(U) The program CROSCORG is a modification of the original cross-correlation program described in Biannual Status Report No. 4. Quantization options of the revised program include (1) hard-clipped, (2) linear N-bit, or (3) floating point quantization. The accuracy of both the linear and the floating point quantization can be specified. The signal array has been increased from a 10,000 word maximum to an 18,900 word array. Different sampling rates are simulated as before by selecting every nth data point from the original arrays for cross-correlation. Finally, the correlation function is scaled to a maximum of 2047 to facilitate D/A processing of the output data.

CCPS

(U) The program CCPS is used to accept information from analog tape data played through the Computer Controlled Playback System. These data were procured by Naval Undersea Warfare Center-San Diego (NUWC-SD) for purposes of automatic recording of auxiliary sonar

data (pulse length, range, etc.) at sea, and output this data in the proper format onto digital tape. The data from the CCPS is in 4-bit BCD form, and is introduced into the computer via the digital inputs on the A/D interface in 12-bit (3 character) format. Program CCPS then translates this to standard 6-bit BCD format and buffers it onto magnetic tape.

SEAINVER

(U) This program converts the output from CCPS to the format desired by NUWC-SD, compatible with the actual sonar parameters associated with the input data, and prints these data in this format.

IMPULSE

(U) This program computes the impulse response of a system, given as input arrays (from magnetic tape), the output signal of the system, and the input signal which caused that output. The process is described more fully below.

HOUSETOP

(U) This program takes as its input (from tape) a 12-bit integer array, which it duplicates in the upper 12 bits of each 24-bit word. This is then D/A converted in increment mode on two channels, giving as an output two identical signals. One of these can then be shifted with respect to the other by any number of samples (or words).

DOPPLER

(U) A further development of HOUSETOP, this program performs the same function, except that it accepts any two arrays as inputs, allowing the shifting of one signal (array) with respect to the other.

TRACE4

(U) This program is a final development of the last two programs mentioned. It accepts any number of input arrays up to four and D/A converts them in increment mode on four channels. Any one of the signals can then be shifted with respect to the others by any desired number of samples. The program employs real-time processing of data as it is being read off magnetic tape, thereby allowing record lengths of up to 10,000 samples for each of the (up to) four records.

(C) The programs HOUSETOP, DOPPLER, and TRACE4 were used in a study of the Doppler measuring capability of linear FM pulses using cross-correlation processing. Two types of Doppler pulses were available from the sea data: "Housetop" data (an up-sweep FM pulse followed immediately by a down-sweep) and "Alternate," or "Split Rooftop" data (up-sweep followed by a delay followed by a down-sweep). Target motion (Doppler) will cause the cross-correlation function between an up-sweep transmission and the resulting echo to be shifted in time relative to the same function at zero-Doppler. The cross-correlation function for a down-swept transmission will also be shifted, but in the opposite direction. By transmitting both types of transmissions with the separation between them accurately known, this shift of the correlation functions can be used as a measure of target Doppler.

(C) The PAIR system proposed use of this technique for Doppler measurement, using housetop transmissions with pulse length $T \cong 80$ msec, Bandwidth $W = 440$ Hz. Data with parameters similar to these were found and digitized.

(C) To determine the discriminability of Doppler by a human operator using PAIR-like parameters ($TW = 64$, $T = 625$), three experiments were performed, all using data with high signal-to-noise

ratio (S/N). The first involved shifting a cross-correlation function from a stern submarine target with respect to itself (see Monthly Letter Report, May 1967), using the program HOUSETOP. It was seen that, for PAIR display parameters in this ideal case, the shift caused by a two kt range-rate (approximately the theoretical Doppler resolution for these parameters) could be discerned. This was obviously not a practical situation, however, since high S/N echoes with up correlation function identical to the down correlation function are not to be encountered with any frequency.

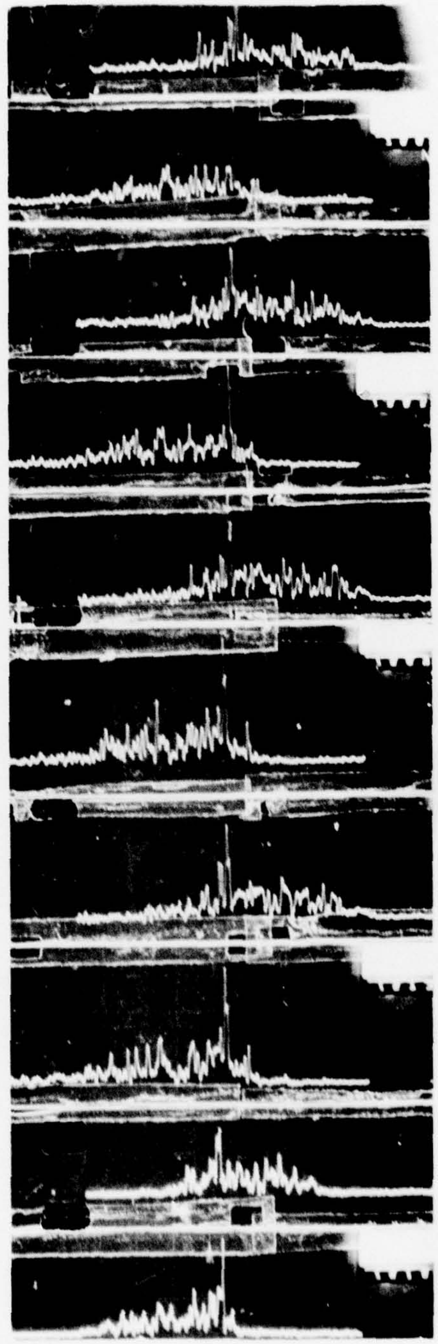
(C) The second experiment used echoes from housetop transmissions. Upon comparing the "up" correlation functions with the "down" correlation functions, it was found that they were greatly dissimilar. The reason for the dissimilarity was that the reflected energy from the down-swept portion of the housetop transmission was acting as high-level noise to the up-correlation function, and vice versa. This effect is seen in Fig. 7 (from Monthly Letter Report, March 1967). Without the very strong highlight present for these signals, no comparison to determine shift could be made.

(C) The results of the second experiment led quickly to the third, a study of the similarity of up and down correlation functions for alternate (split-housetop) transmissions. It was found that, at least for high S/N echoes, the up and down correlation functions from a stern aspect target were quite similar. Program Doppler was then used to shift these functions with respect to each other by controlled amounts, with results as indicated in Fig. 8 (from Monthly Letter Report, May 1967). It is seen that the shift due to Doppler in excess of 4 kt would be recognizable for these conditions.

(C) On the basis of these experiments, it was recommended to the PAIR Project Office that alternate rather than housetop transmissions be adopted, and that the pulse length (and hence, the Doppler

"UP" CORRELATION FUNCTION

"DOWN" CORRELATION FUNCTION

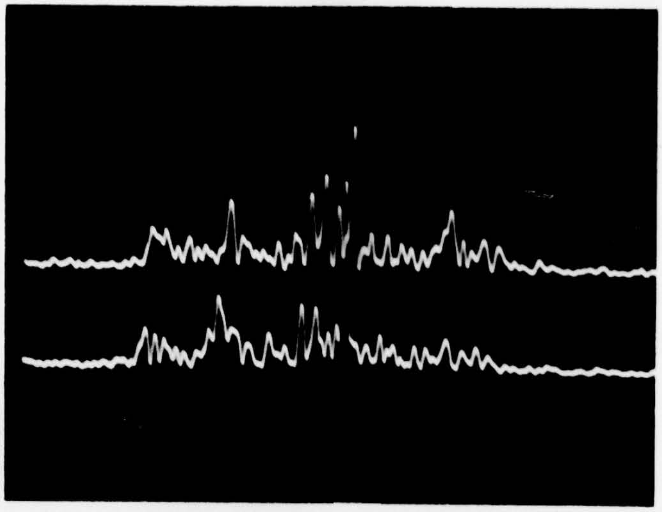


TW = 64
W = 625 Hz
HORIZONTAL SCALE:
20 msec/div

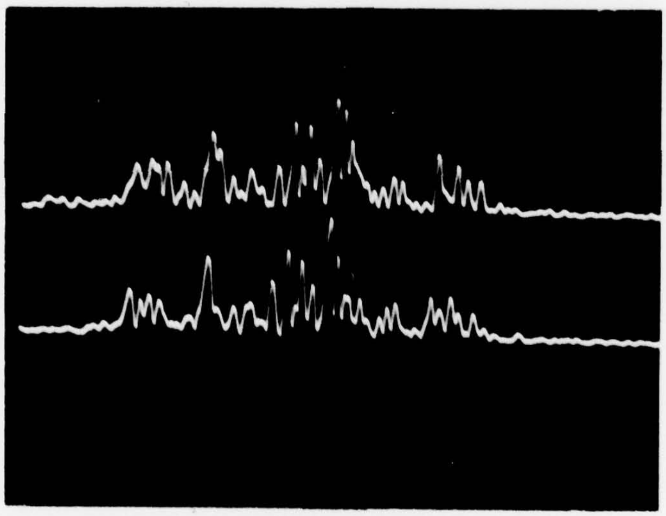
TW = 64
W = 312.5 Hz
HORIZONTAL SCALE:
50 msec/div

FIGURE 7
CORRELATION FUNCTIONS
FOR HOUSETOP TRANSMISSIONS
SUBMARINE ASPECT ANGLE: 195 deg (U)

DRL - UT
DWG BS-67-513
SPP - RFO
5 - 11 - 67



TW = 64, W = 625



TW = 32, W = 625

4 kt DOPPLER – SIMULATED
HORIZONTAL SCALE: 200 msec FULL SCALE

FIGURE 8
SIMULATED PAIR DOPPLER DISPLAY (C)
STERN ASPECT SUBMARINE

DRL - UT
AS-67-869
SPP - RFO
7 - 11 - 67

resolution) be increased as much as practicable. For a linear correlator, it is apparent that the interference mentioned earlier, at least for elongated targets with several reflectors, will generally occur since the energy reflect from the up portion of a housetop transmission will have essentially the same magnitude as that from the down portion. Because a linear correlator measures energy as well as coherence, the interference will appear whenever the input S/N is greater than unity. It therefore seems logical to suggest the use of alternate transmissions for Doppler measurement when linear correlation is employed. It is not yet known whether this same problem would occur for clipped correlation.

(C) Another question which is presently being addressed is the effect of S/N on this type of Doppler measurement. Data have been digitized with noise added, allowing control of the S/N at the equivalent of the input to a correlator (or any other type of processor). Both the signal and noise (from a General Radio wideband random-noise generator) were passed through identical filters and algebraically added. These data have been processed but not displayed in a form, so that definitive statements can be made. It appears, however, that for input peak signal-to-peak noise level ratio of unity (0 dB), the envelope of the alternate transmission cross-correlation functions is fairly well preserved. No data were digitized with S/N less than this, so that more data will probably need processing in order to complete an experiment.

(U) During June a study was undertaken to determine the effects of Doppler on the envelopes of cross-correlation functions for varying parameters. Program GENDATA4 was developed and used for this purpose.

(C) Correlation envelopes were obtained for two sets of parameters. They are the PAIR parameters (TW = 64, T = 160 msec) and the AN/SQS-26 FM classifier parameters (TW = 256, T = 1.16 sec). With

each set two types of correlations were calculated, one for up-slope LFM and one for down-slope LFM. For a given condition, for example, the PAIR parameters using the up-slope LFM, the range rate $\dot{r}$ was allowed to vary from -60 kt to +60 kt.

(C) Some of the correlation envelopes for the PAIR parameters under the conditions just mentioned are shown in Figs. 9 through 11. A considerable amount of information is available from the series of plots shown here. The deterioration of the general shape of the envelope as $\dot{r}$ is increased in magnitude can be observed. Deterioration implies a lowering of the peak correlation, widening of the central peak, splitting of the central peak, etc. Figure 12 is a plot of peak correlation vs Doppler for the same case.

(U) Associated with each point of the plot of Fig. 12 is the number taumax, which is the time shift of the maximum of the correlation function for a given $\dot{r}$. By definition the peak correlation corresponding to $\dot{r}$ = 0 has zero-time shift. Figure 13 is a plot of the time shifts vs $\dot{r}$ for the same parameters. Values of taumax:p are also shown. Taumax:p is calculated from the expression:

$$\text{taumax:p(up-slope)} = -\frac{4\dot{r}T}{c}\,\frac{\frac{1}{2} + \frac{\dot{r}}{c} + \frac{f_o}{W}}{2 + \frac{4\dot{r}}{c} + \frac{4\dot{r}^2}{c^2}} \quad ; \qquad (1)$$

where

T = transmit pulse length,

W = transmit bandwidth,

f_o = center frequency,

c = velocity of sound.

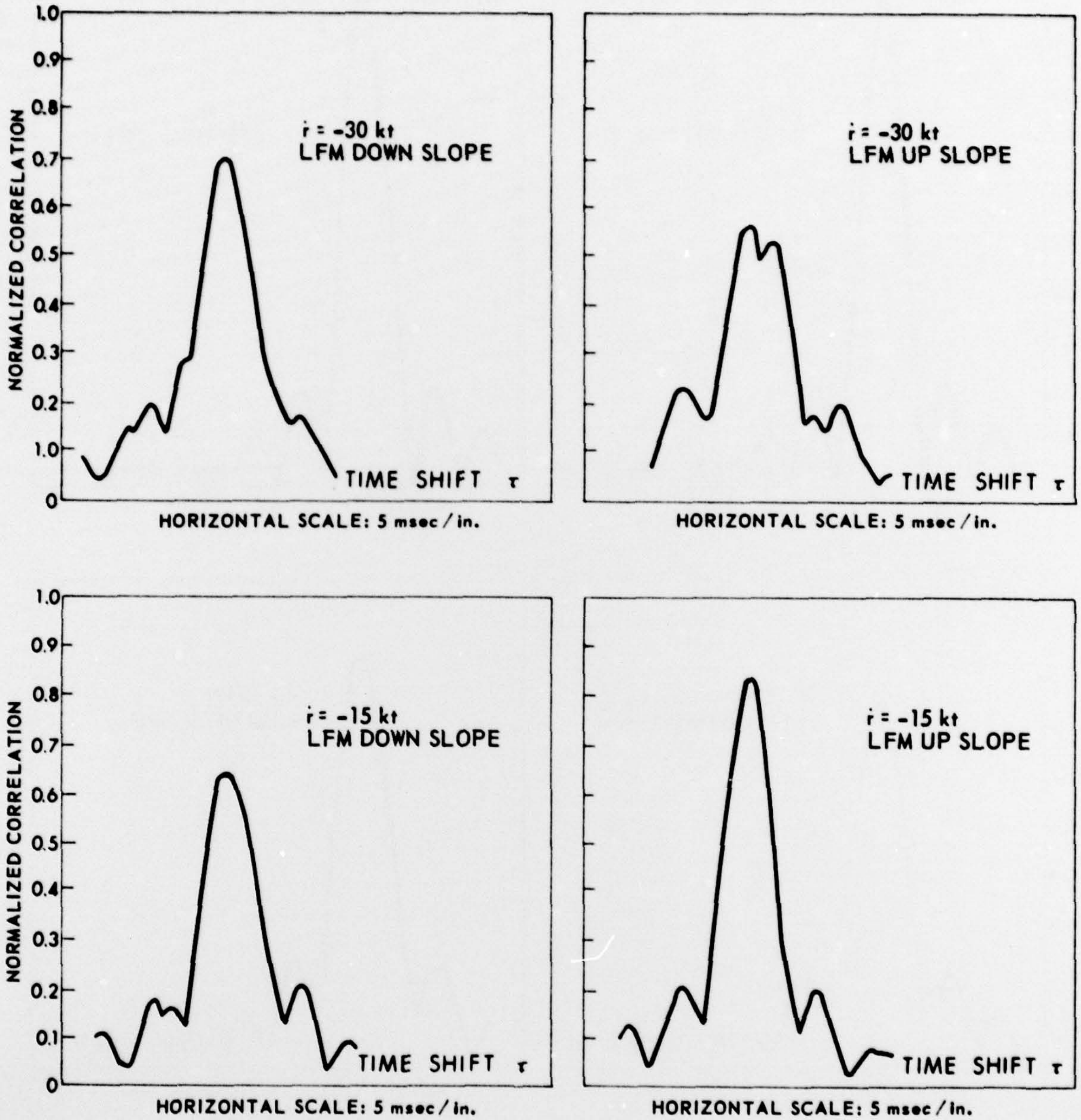


FIGURE 9
EFFECTS OF DOPPLER ON CROSS-CORRELATION FUNCTIONS
T = 160 msec W = 440 f_o = 5000 Hz

DRL - UT
AS-67-1318
TDP - BJB
9-15-67

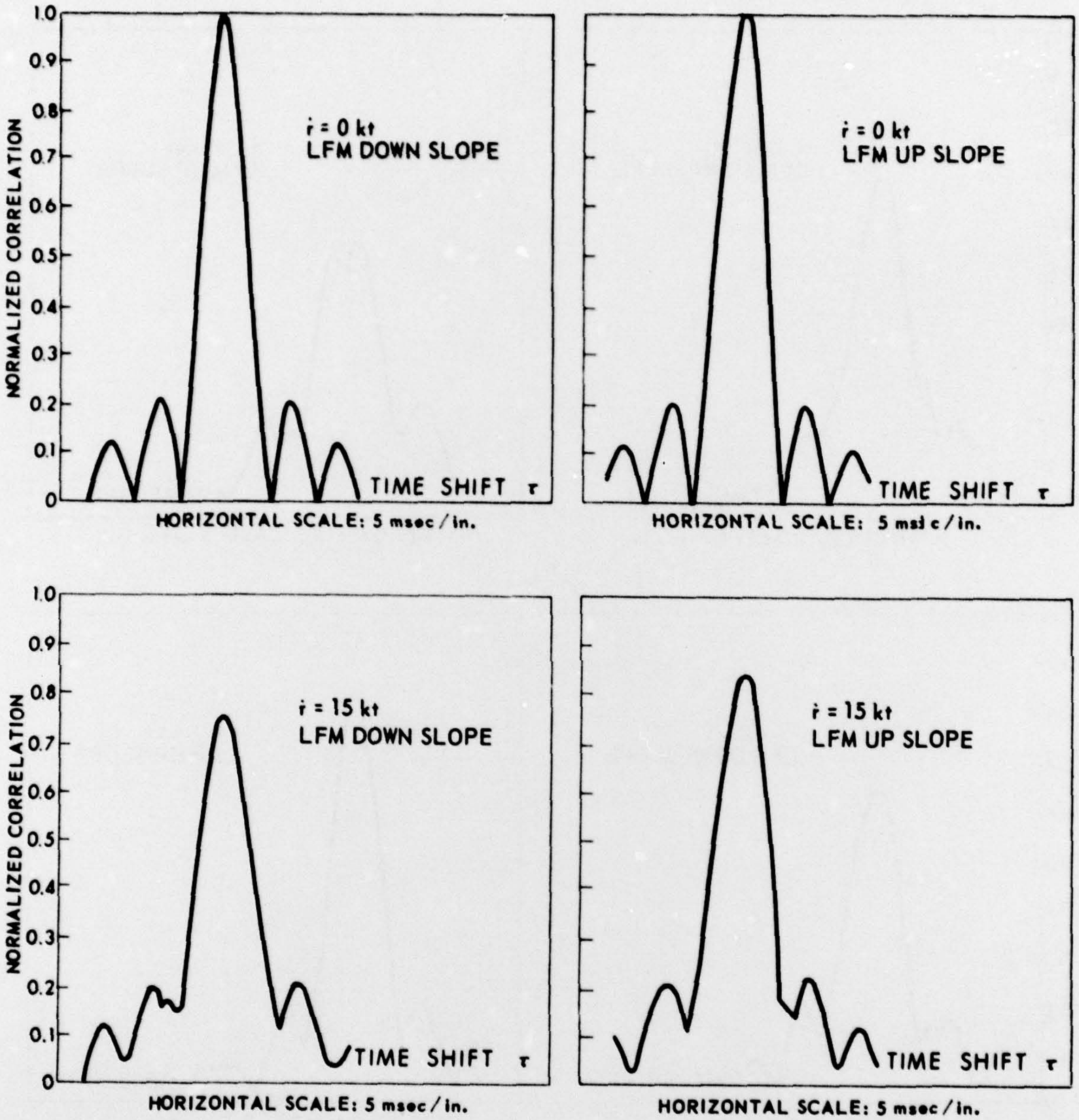


FIGURE 10
EFFECTS OF DOPPLER ON CROSS-CORRELATION FUNCTIONS
T = 160 msec W = 440 f_o = 5000 Hz

DRL - UT
AS-67-1319
TDP - BJB
9-14-67

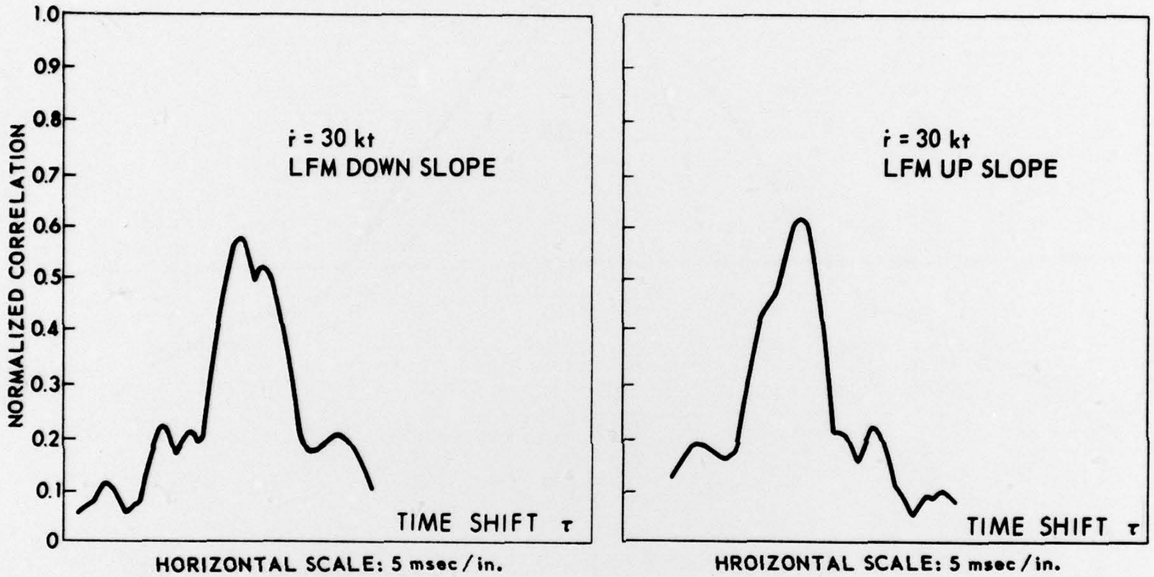


FIGURE 11
EFFECTS OF DOPPLER ON CROSS-CORRELATION FUNCTIONS
T = 160 msec W = 440 f_o = 5000 Hz

DRL - UT
AS-67-1320
TDP - BJB
9-15-67

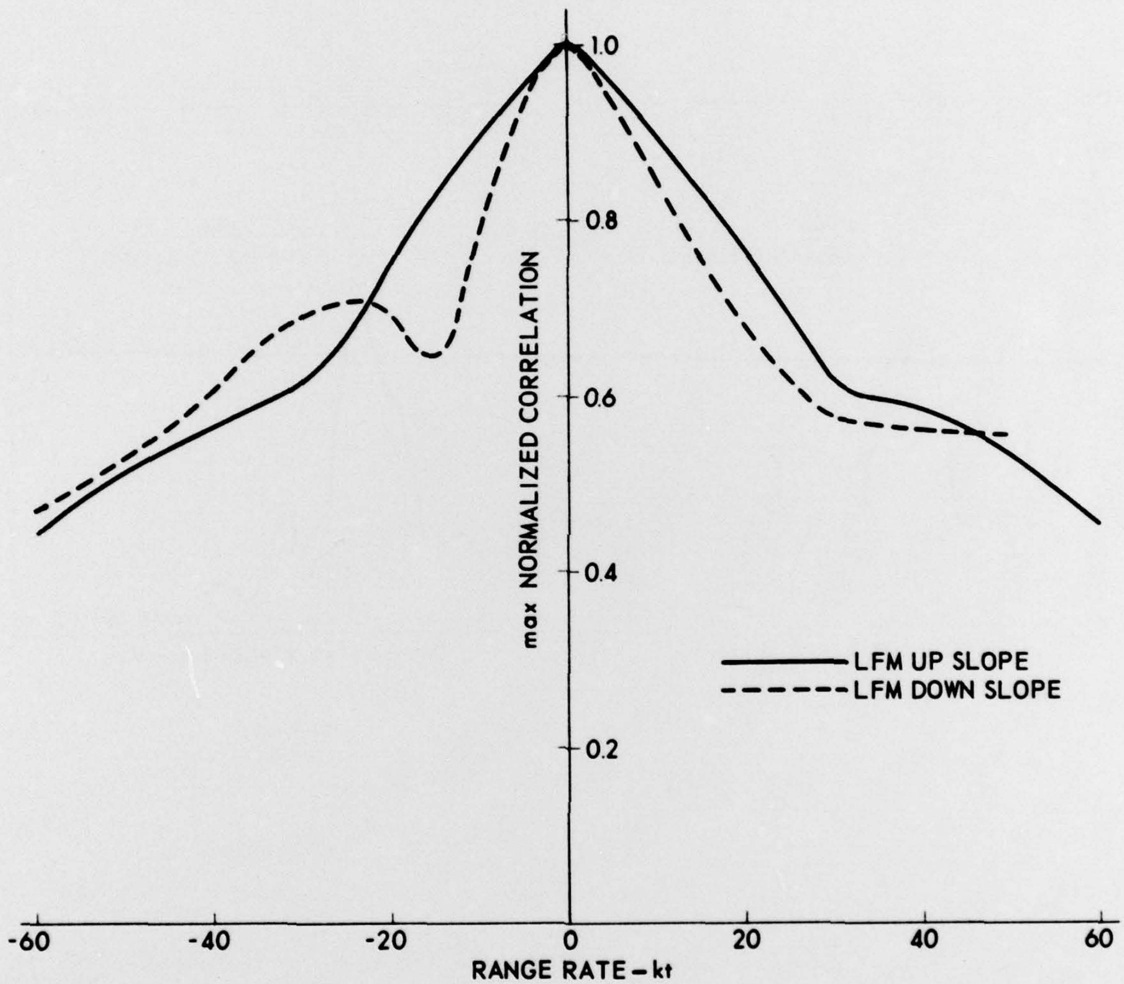


FIGURE 12
MAXIMUM NORMALIZED CORRELATION AS A FUNCTION OF RANGE RATE
T = 160 msec W = 440 f_o = 5000 Hz

DRL - UT
AS-67-1321
TDP-BJB
9-15-67

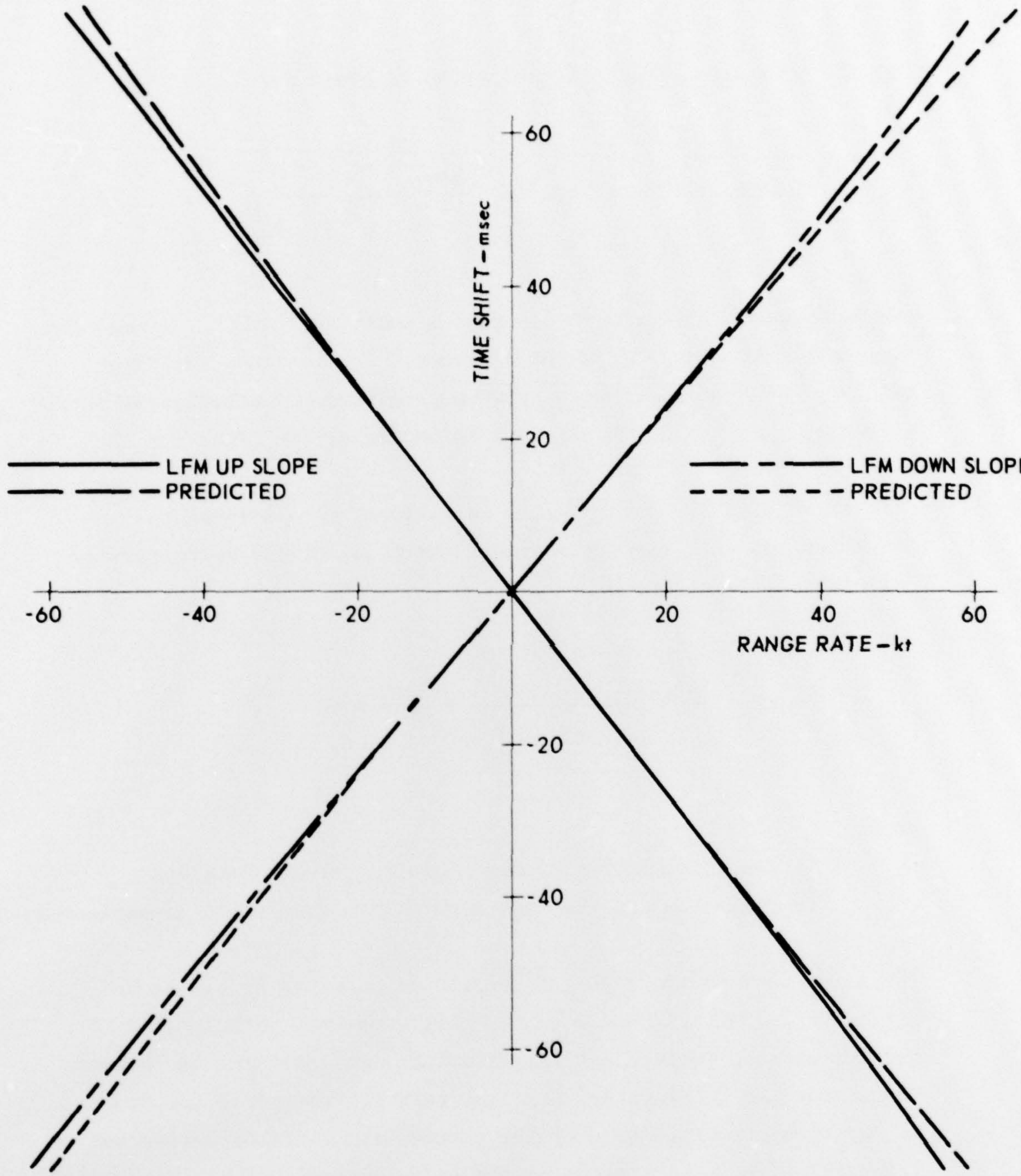


FIGURE 13
TIME SHIFT OF MAXIMUM CORRELATION AS A FUNCTION OF RANGE RATE
T = 160 msec W = 440 f_o = 5000 Hz

DRL - UT
AS-67-1322
TDP-BJB
9-15-67

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For the down-slope case the prediction is given by:

$$\text{taumax:p(down-slope)} = -\frac{4\dot{r}T}{c}\,\frac{\frac{1}{2}+\frac{\dot{r}}{c}-\frac{f_o}{W}}{2+\frac{4\dot{r}}{c}+\frac{4\dot{r}^2}{c^2}} \quad . \qquad (2)$$

(We have adopted the convention that a positive $\dot{r}$ indicates that the target is moving away from the observer.) Notice that for large values of $|\dot{r}|$ the difference between predicted and actual time shift increases. In the future we hope to determine the cause for this.

(U) If an up-slope transmission is followed by a down-slope transmission, then the time between the peaks of the corresponding correlations is given by:

$$|\Delta\tau| = \left|\frac{4\dot{r}T}{c}\,\frac{\frac{f_o}{W}}{1+\frac{2\dot{r}}{c}+\frac{2\dot{r}^2}{c^2}}\right| + \frac{2\dot{r}\Delta T}{c} + \Delta T \quad ; \qquad (3)$$

where

ΔT is the time separating the beginning of the up-slope transmission and the beginning of the down-slope transmission.

The first term on the right of Eq.(3) is obtained by taking the difference of Eq.(1) and Eq. (2). Difference of path lengths of the two signals (because of target motion) necessitates the second term. For the PAIR system, the last term is subtracted out, but an error may be introduced by the second term. The magnitude and potential effects of this error are being studied. This, along with other findings during this study, will be described in a technical report later.

(U) The program IMPULSE, described above, was written and tested during June. The philosophy behind this undertaking is as follows: An echo $Y(t)$ reflected from a target is related to the transmitted signal $(X(t))$ by the equation:

$$Y(t) = \int_{-\infty}^{\infty} X(t-\tau)\ h(\tau)d\tau \quad ,$$

where

$h(t)$ is the impulse response of the target.

Taking the Fourier transform of both sides of this equation results in $Y(w) = X(w)\ h(w)$. Solving for $h(w)$ and taking its inverse Fourier transform results in the impulse response of the target in the time domain. Since the impulse response for a particular target is unique, it can theoretically be used as a classification criterion.

(U) The program IMPULSE calculates $h(t)$, given both $Y(t)$ and $X(t)$ as real input digitized arrays which are read in from tapes. A fast Fourier transform of $Y(t)$ and $X(t)$ is taken using an algorithm method, credited to Cooley and Tukey. Because of the algorithm method, the number of sample points of $X(t)$ and $Y(t)$ must be equal to 2^N, where N is some integer (not greater than 12 for the CDC 3200). After the transforms have been taken, $X(w)$ and $Y(w)$ are complex numbers; in calculating $h(w)$, it is rationalized to the form

$$h(w) = \frac{Y(w)\ X^*(w)}{X(w)\ X^*(w)} \quad .$$

The inverse transform of $h(w)$ converts the impulse response back into the time domain. The real part of the impulse response array can then be printed, plotted, or stored on tape. During execution of the program, the disk is used for temporary storage by means of simulated tape instruction.

(U) The program has been checked by convolving $X(t)$ with the calculated $h(t)$, getting $Y(t)$. Both analytic and actual data have been used to test the program. For all real data the impulse response was essentially real; i.e., the imaginary part was very small with respect to the real part. The analytic data were a series of square-wave impulses used as $X(t)$, and $Y(t)$ was a time delayed form of $X(t)$. The result was a delta-function at each lag time in the impulse response array, as shown in Fig. 14A. Actual data consisting of an FM pulse, considering the pulse itself as though it were an echo, have been processed with the result shown in Fig. 14B. It is seen that, again, a delta-function was obtained. Real data consisting of an FM pulse and the resulting echo from the stern aspect of a submarine, as well as a cw pulse and echo from a 7 in. hollow aluminum sphere have also been processed. The results from the real echoes are being examined; no conclusive statements can be made at this point.

(U) During this report period a study was undertaken to determine whether a method "better" for quantizing signals than linear quantization could be found. A "better" method would provide either more dynamic range with sufficient accuracy using the same storage, or sufficient accuracy using less storage, or both.

(U) A logical choice for a method is that used in computers, called floating point representation, whereby numbers are represented by a multiplier and a power of 2 (e.g., $24 = 3 \times 2^3$). If a fixed number of bits are allotted to the multiplier and a fixed number to the exponent, this technique provides a percentage accuracy of representation which varies over a small range for amplitudes less than or equal to the maximum. (For linear quantization the accuracy decreases with decreasing signal amplitude.) For a given number of total bits available, floating point representation allows a choice of methods. For example, with five bits

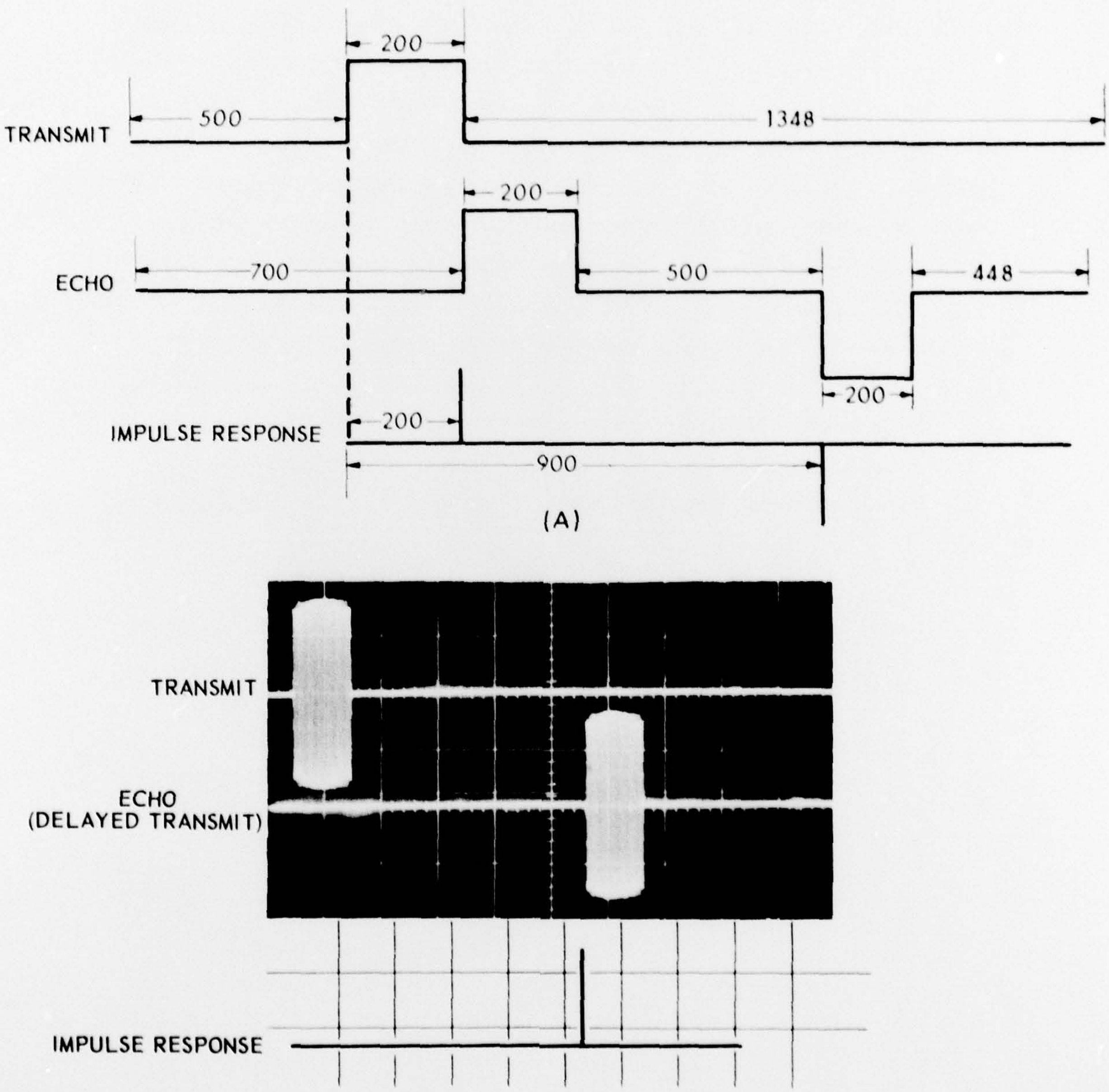

FIGURE 14
COMPUTED IMPULSE RESPONSES FOR TEST DATA

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available, we could use all five as the multiplier, making the exponential equal to unity (exponent equal to zero). The maximum number in this case is $2^4 = 16$. On the other hand, we could use four of the bits as the exponent of 2, making the maximum number $2^{16} = 65,536$, with the fifth bit a sign bit. A much wider range of numbers can be represented in this way, but accuracy of representation is lost. We can increase the accuracy and decrease the range by adding multiplier bits and reducing the number of exponent bits. For example, two multiplier bits, two exponent bits and a sign bit, so that the maximum number is $3 \times 2^3 = 24$, and the accuracy of representation is approximately 1/6 = 16 2/3 percent.

(U) Program CROSCORG has been used to demonstrate the results of this type of quantization. Real data (beam submarine) has been processed (cross-correlated) using data quantized in the following way:

Reference Signal (Transmit)		Echo	
Multiplier	Exponent	Multiplier	Exponent
12 bits (standard)		12 bits	
1 bit	3 bits	2 bits	4 bits
2 bits	4 bits	2 bits	4 bits
2 bits	4 bits	3 bits	3 bits
3 bits	3 bits	2 bits	4 bits
3 bits	3 bits	3 bits	3 bits
3 bits	3 bits	4 bits	2 bits
4 bits	2 bits	3 bits	3 bits
4 bits	2 bits	4 bits	2 bits
3 bits	0 bits	1 bit	1 bit
3 bits	0 bits	1 bit	2 bits
3 bits	0 bits	1 bit	3 bits
3 bits	0 bits	1 bit	0 bits
3 bits	0 bits	3 bits	3 bits
1 bit	0 bits	1 bit	1 bit
1 bit	0 bits	1 bit	2 bits
1 bit	0 bits	1 bit	3 bits

(C) One restriction applied in establishing these experiments was to keep the amount of storage required close to what is being used for PAIR, namely, 5 bits total for the signal and 1 bit for the reference. Another constraint to which data were held is that the maximum value not be allowed to exceed the capacity of the storage, regardless of the quantization method used. For all the cases tested in this manner, the deviation of the envelope from the "standard" case (12 bit linear quantization on both signals) was slight. The greatest deviation from the standard case occurred when the reference array was clipped, as it is in PAIR. This deviation seemed to persist regardless of the quantization on the echo. It should be repeated that the deviation was relatively slight even for the worst case tested. Using a 2 bit quantization on the reference and sign plus 4 bit exponent quantization for the echo resulted in good agreement with the standard. This quantization allows a range of from 1 to $2^{16} = 65{,}536$, a tremendous dynamic range. More work needs to be done to determine the inaccuracies introduced, especially when the signal is small compared to the largest number. It is expected that a technical report will be issued on this study in the near future.

(U) Work was begun on the design of an analog interface to the A/D-D/A converter. Present plans by the computer branch call for a patch-panel interface with the A/D-D/A converter, allowing each group with a patch-panel board to wire an experiment on the board, then set up the experiment by simply plugging the board into the patch-panel interface. The analog interface which has been designed will tie directly to the patch-panel board. It will include buffer amplifiers, attenuators, adders, envelope detectors, filters, and all other components used in typical experiments. These components will be interconnected via switches, allowing changing of experimental set-ups by the turning of a few switches. The interface will also provide the means for implementing a computer warning system

developed by Systems Analysis. This system consists of a computer subroutine which will be added to all Systems Analysis programs. This routine provides a signal through the D/A converter which will be used to drive a speaker. The signal is coded by the parameters used to call the subroutine. These parameters, it is anticipated, will be taken from a particular computer job card, so that the warning signal can be coded for any particular person, program, section, branch, or whatever is most convenient or informative to the user. Because the D/A converter contains 24 digital output lines, 24 different speaker systems can be addressed independently. By tying different lines to different locations in the laboratory and making the digital line number a parameter used to call the subroutine, a lab-wide warning system could be implemented. This is being considered after the move to the new building.

(U) During this report period the A/D facility was used to obtain data in digitized form for several groups of investigators. Systems Analysis personnel assisted in the setting up and digitizing processes for all these groups. The groups and the types of data obtained by each are described below:

Group	Transmission Mode	Pre-processing	Target
Purdue University	Normal SQS-23	Envelope Detection	≈300 sub, ≈250 nonsub
G. E. TEMPO	Normal SQS-23 short pulse	Bandpass filtering	sub, nonsub, several hundred each
NEL, Code 3180	SDT-FM	Bandpass filtering	sub, nonsub, several hundred each

These data were reformatted onto tapes loaned by the different groups--the original digitized data remain at DRL.

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